Derivation of Default Closure Levels

A8.1 Introduction

The Default Closure Levels were determined for commercial/industrial (on site) and residential (off site) surface soil (direct contact), subsurface soil (migration to ground water), and the ground water. The equations used to determine these closure levels are presented in Appendix 8.2 and the default input parameters are in Appendix 8.3. As with RISC, the default soil closure levels are the lowest of the soil attenuation capacity, surface soil or subsurface soil closure levels. For off site contamination, residential and industrial properties are evaluated with residential exposure assumptions.

The general procedure is to determine the hazard quotient (HQ) for each fraction of the default composition of 1,000 mg/kg of a theoretical fuel. The hazard quotients are summed to derive the hazard index (HI) for the default fuel. A proportion of the HI relative to an HI=1 is then used to determine the default TPH concentration that would have an HI=1. This is the default closure level. For diesel fuel sites, limited experience has shown that some fractionation analyses resulted in a lower safe closure level than the default composition yielded. Since the default closure level is based upon a theoretical diesel fuel composition, an uncertainty factor of 0.5X is used in the calculation for diesel fuel default closure levels. As more experience with actual fuels in Indiana is accumulated, the default composition and uncertainty factor may be adjusted. Site specific closure levels (non-default) will not need to be adjusted for uncertainty.

$$\text{TPH}_{closure} = [1{,}000 \text{ mg/kg } \times 1.0 \text{ HI/ HI}_{default\ fuel}] \times 0.5 \text{ (diesel fuel only)}$$

For default, non-carcinogen closure levels, each of the 12 TPH fractions are assumed to be in proportions that have been based upon the Washington Department of Ecology for gasoline and diesel fuel (Table A.1).

Table A.1 Default Percent Compositions of Selected Fuels

Component	Gasoline Percentage	Diesel Percentage
Aliphatic		
EC 5-6	23.0	0.06
EC > 6-8	22.0	0.31
EC > 8-10	9.0	1.02
EC > 10-12	3.0	4.18
EC > 12-16	0.0	30.00
EC > 16-21	0.0	42.60
EC > 21-36	0.0	0.00
Aromatic		
EC 8-10	41.0	0.94
EC > 10-12	2.0	3.53
EC > 12-16	0.0	9.68
EC > 16-21	0.0	7.61
EC > 21-36	0.0	0.07
TOTAL	100.00	100.00

A8.1.1   Derivation of Surface Soil Closure Levels

Assuming the TPH concentration of a particular fuel in the soil is 1,000 mg/kg, calculate the concentration for each fraction using the percent composition in Table A.1. For example, if the aliphatic EC >8 – 10 fraction is 1.02% of diesel, that represents a soil concentration of 10.2 mg/kg. Determine the Hazard Quotient (HQ) for each fraction using equation A2-1, (Appendix 8.2) and the fraction specific values found in Appendix 8.3.

Sum the HQs for the Hazard Index (HI). Normalize the HI to 1.0 using a simple proportionality. For example, assume in a commercial/industrial exposure scenario that 1,000 mg/kg of diesel yields an HI = 0.12776 (the sum of the Hazard Quotients for each of the 12 fractions). The commercial/industrial surface soil closure level is:

$$\text{TPH}_{closure} = 1{,}000 \text{ mg/kg} \quad X \quad 1.0 \text{ HI}/ 0.12776 \text{ HI}_{default\ fuel} \quad X \ 0.5 \text{ (diesel fuel only)}$$

$$\text{TPH}_{closure} = 7825 \text{ mg/kg (the soil concentration with an HI = 1) X 0.5}$$
$$= 3{,}912 \text{ mg/kg}$$

This procedure was used to determine the default closure levels for each fuel type and can be used to determine site-specific (non-default) TPH closure levels by fractionation analysis of on site contamination.

Table A.2 Commercial/Industrial Diesel Surface Soil Hazard Quotients

Fraction	% Composition	Csoil in 1,000 mg/kg of TPH	HQ
Aliphatic EC 5-6	0.06	0.6	7.5E-5
Aliphatic EC> 6-8	0.31	3.1	2.6E-4
Aliphatic EC> 8-10	1.02	10.2	8.04E-3
Aliphatic EC> 10-12	4.18	41.8	1.4E-2
Aliphatic EC> 12-16	30.00	300.0	3.9E-2
Aliphatic EC> 16-21	42.60	426.0	4.3E-4
Aliphatic EC> 21-36	0	0	0
Aromatic EC 8-10	0.94	9.4	1.1E-2
Aromatic EC> 10-12	3.53	35.3	2.2E-2
Aromatic EC> 12-16	9.68	96.8	2.7E-2
Aromatic EC> 16-21	7.61	76.1	5.2E-3
Aromatic EC> 21-36	0.07	0.7	4.7E-5
TOTAL	100	1,000	0.12776

A8.1.2   Derivation of Subsurface Soil Closure Levels

Default subsurface soil closure levels are based upon their potential to leach contaminants into the ground water and produce an HI = 1. Default closure levels in subsurface soil were determined using an iterative approach based upon the leaching equation A2-3, (Appendix 8.2 and RISC Equation 7-1, RISC Technical Guide) and the fraction specific values found in Appendix 8.3. Using a theoretical 1,000 mg/kg TPH, the percent composition of each fraction was converted to an equivalent subsurface soil concentration. The theoretical ground water concentration for each fraction was then determined.

The ground water HQ for each fraction concentration was calculated using the appropriate equation for commercial/industrial exposures (Equation A2-4, Appendix 8.2) and residential exposures (Equation A2-5, Appendix 8.2). The HQs were summed for the HI and then a simple proportionality was used to determine a concentration in the subsurface soil that corresponds to an HI of 1.0 in the ground water. An example using the default composition for diesel follows.

Table A.3 Derivation of the Commercial/Industrial Diesel Ground Water Hazard Quotients

Fraction	Koc (ml/g)	% Composition	Csoil in 1,000 mg/kg of TPH	Cgw (mg/l)	HQ from GW concentration
Aliphatic EC 5-6	8 E+2	0.06	0.6	9.8E-3	2.9E-5
Aliphatic EC> 6-8	3.8 E+3	0.31	3.1	2.5E-2	7.3E-5
Aliphatic EC> 8-10	3.0 E+04	1.02	10.2	1.5E-2	2.6E-3
Aliphatic EC> 10-12	2.4 E+05	4.18	41.8	8.5E-3	1.40E-3
Aliphatic EC> 12-16	5.4 E+06	30.00	300	12.7E-3	4.5E-4
Aliphatic EC> 16-21	9.5 E+09	42.6	426	1.3E-6	5.5E-9
Aliphatic EC> 21-36	1.1E+13	0.0	0.0	0.0	0.0
Aromatic EC 8-10	1.6 E+03	0.94	9.4	2.7 E-1	6.7E-2
Aromatic EC> 10-12	2.5 E+03	3.53	35.3	6.7E-1	0.17E-1
Aromatic EC> 12-16	5.0 E+03	9.68	96.8	9.3E-1	0.23E-1
Aromatic EC> 16-21	1.6 E+04	7.61	76.1	2.3E-1	3.8E-2
Aromatic EC> 21-36	1.3 E+05	0.07	0.7	2.6E-4	4.4E-5
TOTAL			1,000		**HI = 0.507**

1,000 mg/kg of this diesel fuel in the subsoil would result in a ground water HI = 0.507

Using a simple proportionality, an HI of 1.0 in the ground water would result from a TPH concentration in the subsurface soil of 1,970 mg/kg. Adjusted for uncertainty (0.5X), the subsurface soil diesel commercial/industrial closure level would be 985 mg/kg.

A8.1.3   Derivation of the Ground Water Closure Levels

The ground water concentration of each fraction cannot exceed solubility. Where the predicted ground water concentration exceeds solubility, (see Appendix 8.3) the solubility concentration is used. Predicted concentrations that are greater than the solubility concentration are indicated in parentheses in the last column of table A.4.

Table A.4 Derivation of the Default Ground Water Closure Levels

Fraction	Cgw (mg/l)
Aliphatic EC 5-6	9.8E-3
Aliphatic EC 6-8	2.5E-2
Aliphatic EC 8-10	1.5E-2
Aliphatic EC 10-12	8.5E-3
Aliphatic EC 12-16	7.6E-4 (1.4E-3)
Aliphatic EC 16-21	1.3E-6
Aliphatic EC 21-36	0.0
Aromatic EC 8-10	2.7E-1
Aromatic EC 10-12	6.7E-1
Aromatic EC 12-16	9.3E-1
Aromatic EC 16-21	2.3E-1
Aromatic EC 21-36	2.3E-4
TOTAL:	2.16 mg/l

Corrected for solubility, the default commercial/industrial ground water diesel fuel TPH concentration is 1.08 (2.16 X 0.5) or 1.1 mg/l. This derivation is for the non-cancer, human health based closure levels of diesel TPH. Also, the COC concentrations must not exceed their default (or site specific) closure levels and no free product may be present. Table A.5 presents the results of the default closure level concentrations for gasoline and diesel.

Table A.5 Default Closure Levels

Closure Table

Fuel Type	Commercial/Industrial					Residential				
	Soil				Ground Water	Soil				Ground Water
	Soil Attenuation Capacity (mg/kg) Surface/ Subsurface	Soil Direct (mg/kg)	Migration to Ground Water (mg/kg)	Default Closure Level (mg/kg)	Default Closure Level (mg/l)	Soil Attenuation Capacity (mg/kg) Surface/ Subsurface	Soil Direct (mg/kg)	Migration to Ground Water (mg/kg)	Default Closure Level (mg/kg)	Default Closure Level (mg/l)
Gasoline	6,000 / 2,000	1,540	327	330	3.0	6,000 / 2,000	795	24.7	25	0.22
Diesel	6,000 / 2,000	3912	985	1,000	1.1	6,000 / 2,000	1593	79.1	80	0.1

A8.2-1   Industrial Surface soil

$$HQ = \frac{Cs \ x \ EF \ x \ ED\left[\dfrac{IngSoil + (SA \ x \ AF \ x \ ABS)}{RfDo \ x \ 10^6} + \left(\dfrac{InhRate}{RfDi}\left(\dfrac{1}{VF} + 7.6 \ x \ 10^{-10}\right)\right)\right]}{BW \ x \ ATn \ x \ 365 \ days \ / \ yr}$$

Where:
HQ = Hazard Quotient
Cs = Concentration in soil, (mg/kg)
EF = Exposure Fequency (250 days/year)
ED = Exposure Duration (default at 25 years)
IngSoil = Soil ingestion rate (default at 50 mg/day)
SA = Skin Surface Area (default at 3160 cm^2)
AF = Soil to Skin Adherence Factor (default at 0.5 mg/cm^2-day)
ABS = Skin absorbance (default at 0.1 for TPH fractions)
InhRate = Inhalation Rate (default at 20 m^3/day)
BW = Body weight, (default at 70 kg)
ATn = Averaging time noncarcinogens (default at 25 years)
VF = Volatilization Factor, calculated as per 1996 EPA soil screening guidance
RfDo = Reference Dose, oral (chemical specific, mg/kg-day)
RfDi = Reference Dose, inhalation (chemical specific, mg/kg-day)
7.6 x 10^{-10} = 1/ PEF (Particulate Emission Factor, from 1996 EPA soil Screening Guidance)

A8.2-2   Residential Surface Soils

$$HQ = \frac{Cs \ x \ EF \ x\left[\left(\dfrac{IngFadj + (SFSadj \ x \ ABS)}{RfDo \ x \ 10^6}\right) + \left(\dfrac{InhFadj}{RfDi}\left(\dfrac{1}{VF} + 7.6 \ x \ 10^{-10}\right)\right)\right]}{ATn \ x \ 365 \ days \ / \ yr}$$

Where:
HQ = Hazard Quotient
Cs = Concentration in soil, (mg/kg)
EF = Exposure frequency, (default at 350 days/year)
IngFadj = Soil ingestion rate age adjusted, (default at 114 mg-yr/kg-day) (see below)
SFSadj = Skin Surface Area age adjusted, (default at 1,257 mg-yr/kg-day) (see below)

ABS = Skin absorbance rate, (unitless, default at 0.1 for TPH fractions)
InhFadj = Inhalation factor age adjusted, (default at 9.9 m^3-yr/kg-day) (see below)
ATn = Averaging time noncarcinogens, (default at 30 years)
VF = Volatilization Factor, calculated as per 1996 EPA soil screening guidance (chemical specific, mg/kg-day)
RfDo = Reference Dose, oral (chemical specific, mg/kg-day)
RfDi = Reference Dose, inhalation (chemical specific, mg/kg-day)

7.6×10^{-10} = 1/ PEF (Particulate Emission Factor, from 1996 EPA Soil Screening Guidance)

The concentrations of individual compounds (benzene, PAHs, etc) should be compared to their RISC default closure levels.

A8.2-3   Subsurface Soil Leaching to Ground Water (Equation 7-1 from Technical Guide)

$$Cgw = \frac{Csoil}{DAF\left[Koc \; x \; foc + \left(\frac{\theta\omega + \theta aH'}{Pb} \right) \right]}$$

Where:
Cgw = Concentration in groundwater, (mg/l)
Csoil = Concentration in soil, (mg/kg)
Koc = Organic Carbon Partitioning Coefficient, (chemical specific, l/kg)
foc = Fraction organic carbon in subsurface soil, (0.002 g/g)
θ_w = Water filled soil porosity, (default at 0.3 l water/l soil,)
θ_a = Air filled soil porosity, (default at 0.134 l air/l soil)
H' = Henry's Law Constant, HLC x 41 (chemical specific, dimensionless)
P_b = Dry soil bulk density, (default at 1.5 kg/l)
DAF = Dilution attenuation factor (default at 20)

A8.2-4   Commercial/Industrial Ground Water (Non-Carcinogenic)

$$HQ = \frac{Cgw \; x \; EF \; x \; ED \; x \; \frac{IngRate}{RfDo}}{BW \; x \; ATn \; x \; 365 \; days \; / \; yr}$$

Where:
HQ = Hazard Quotient
Cgw = Concentration in water, (mg/l)
EF = Exposure frequency, (default at 250 days/year)
ED = Exposure Duration, (default at 25 years)
IngRate = Water ingestion rate, (default at 1.0 l/day)
BW = Body weight, (default at 70 kg)
ATn = Averaging time non-carcinogens, (default at 25 years)
RfDo = Reference Dose, oral (chemical specific)

A8.2-5   Residential Ground Water (Non-Carcinogenic)

$$HQ = \frac{Cgw \ x \ EF \ x \ ED \left[\left(\frac{IngR}{RfDo} \right) + \left(\frac{InhR \ x \ K}{RfDi} \right) \right]}{BW \ x \ ATn \ x \ 365 \, days/yr}$$

Where:
Cgw = Concentration in GW, mg/l
HQ = Hazard Quotient
EF = Exposure Frequency, (default at 350 days/yr)
ED = Exposure Duration, (default at 30 years)
IngR = Ingestion rate, (default at 2.0 l/day)
InhR = Inhalation rate, (default at 15 m^3/day)
K = Indoor volatilization factor from GW, (default at 0.5 l/m^3)
RfDo = Oral reference dose (chemical specific, mg/kg-day)
RfDi = Inhalation reference dose (chemical specific, mg/kg-day)
BW = Body weight, (default at 70 kg)
ATn = Noncarcinogenic averaging time, (default at 30 years)

Components	RfDo mg/kg-day	RfDi mg/kg-day	S mg/l	H' (41xH)	Koc l/kg
Aliphatic EC > 5-6	1.7	1.7	3.60E+01	4.70E+01	8.00E+02
Aliphatic EC > 6-8	1.7	1.7	5.40E+00	5.00E+01	3.80E+03
Aliphatic EC > 8-10	0.03	0.085	4.30E-01	5.50E+01	3.00E+04
Aliphatic EC > 10-12	0.03	0.085	3.40E-02	6.00E+01	2.40E+05
Aliphatic EC > 12-16	0.03	0.085	7.60E-04	6.90E+01	5.40E+06
Aliphatic EC > 16-21	2		1.30E-06	8.70E+01	9.50E+09
Aliphatic EC > 21-36	2		1.50E-11	1.30E+02	1.10E+13
Aromatic EC > 8-10	0.02	0.02	6.50E+01	3.90E-01	1.60E+03
Aromatic EC > 10-12	0.02	0.02	2.50E+01	1.30E-01	2.50E+03
Aromatic EC > 12-16	0.02	0.02	5.80E+00	2.80E-02	5.00E+03
Aromatic EC > 16-21	0.03		5.10E-01	1.90E-03	1.60E+04
Aromatic EC > 21-36	0.03		6.60E-03	1.70E-05	1.30E+05